THE INFLUENCE OF EMPTYING FREQUENCY OF PITFALL TRAPS ON THE CAPTURE OF EPIGEAL INVERTEBRATES, ESPECIALLY *PTEROSTICHUS MADIDUS* (COLEOPTERA: CARABIDAE)

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Abstract

Pitfall trapping has many inadequacies but remains the most used method of collecting epigeal invertebrates. Trap data are often standardised to numbers per day, however, invertebrates already captured may cause attraction making this standardisation invalid. To test for attraction, pitfall traps were emptied at different frequencies and the impact on capture examined. The catch comprised 83% Coleoptera, of which 90% were *Pterostichus madidus* Fabricius. Traps which were emptied after six or nine days had higher capture rates of *P. madidus* than those emptied daily or every two or three days. Staphylinidae and Araneae catches were unaffected by emptying frequency.

Introduction

Pitfall trapping is the most frequently used method of collecting epigeal invertebrates in experimental studies because it is cheap and quick, allowing many samples to be taken (Adis, 1979). However, there are many well-known problems associated with the use of pitfall traps and although the technique provides some estimation of diversity for Carabidae (Ulber & Wolf-Schwerin, 1995) it is considered an unsuitable method for estimating abundance because the capture rate is a result of abundance, activity and species trappability (Greenslade, 1964; Luff, 1975). Observations of beetle behaviour at pitfall traps have highlighted many of their inadequacies (Halsall & Wratten, 1988). There have also been periodic reviews emphasising the need for caution when interpreting pitfall data (Luff, 1975; Adis, 1979; Sunderland *et al.*, 1995). In addition, many different forms of trap are used, containing a variety of trapping solutions, some of which are strong attractants, such as ethylene glycol (Holopainen & Varis, 1986; Weeks & McIntyre, 1997). Moreover, the number of days over which traps remain open often differs and this may create additional bias if attraction or repellency occurs, although whether emptying frequency influences capture rate has not been investigated. This information is needed if comparisons are to be reliably made between and within studies where the total capture has been adjusted to a number per trap per day. Information on emptying frequency may also be used to optimise sample size or used to ensure that no attraction occurs through the adoption of an appropriate emptying frequency.

Many of the problems associated with pitfall trapping were listed by Adis (1979), however emptying frequency was not discussed except for the recommendation that only season-long trapping should be conducted with an emptying frequency of 2–4 times a month. In many studies this is not logistically or financially possible and instead periodic trapping is conducted. In this study, the influence of the frequency of emptying pitfall traps on the total numbers of captured invertebrates was investigated in a pea field in southern England.

Materials and methods

An off-set grid of pitfall traps with 40 × 20 m spacing was set up across six arable fields in April 2000 in Dorset, UK (Holland *et al.*, 2004). A block of fifty sampling positions centrally located in one of these fields (a fodder-pea field) was utilised for this study. At each position, a single 6 cm diameter trap half-filled with 50% ethylene glycol solution was used, protected by a plastic rain cover mounted on nails. Ten positions were randomly allocated to five time treatments. The initial aim was to empty pitfalls and replace with new traps every 1, 2, 3, 6, or 12 days for a 12-day period, starting 24 July 2000. However, trapping had to cease after 9 days to allow farming operations to continue, therefore for data analysis trapping was considered over two time periods. All invertebrates were removed and stored in 70% alcohol. Carabidae and Staphylinidae were identified to species or genus, Araneae to family. Catches were totalled over the nine days for each position emptied every 1, 3 and 9 days. Catches were totalled over the first six days for traps emptied every 1, 2, 3 and 6 days. Totalled catches at each position were transformed to $\log_{10}(x+1)$, and analysis of variance (ANOVA) applied for the major groups.

Results

The catch comprised 83% Coleoptera, of which 90% was *Pterostichus madidus* Fabr. (Table 1). The other Carabidae captured were those typically found on arable farmland such as *Anchomenus dorsalis* Pontoppidan, *Amara* spp., *Calathus fuscipes* Goeze, *Harpalus rufipes* De Geer, *Loricera pilicornis* Fabr., *Notiophilus bigutattus* Fabr. and *P. melanarius* Illiger. Staphylinidae were predominantly *Philonthus cognatus* Stephens and *Tachyporus* species.

The frequency of emptying of traps had a significant effect on the catches of *P. madidus*, total Carabidae and total Coleoptera over both the six- and nine-day trials, and of *P. melanarius* in the nine-day trial (Tables 2a and b). No other coleopteran species was captured in sufficient numbers for statistical analysis. When *P. madidus* captures were excluded from the analyses then there were no significant effects for total Carabidae or total Coleoptera. In the six-day trial there were according to Fisher's LSD test significant differences in the capture rate for traps emptied every 1 ($P=0.001$), 2 ($P=0.015$) and 3 ($P=0.005$) days compared to 6 days (Table 2a). For the nine-day trial, capture differed significantly for traps emptied every 1 ($P=0.002$) and 3 ($P=0.005$) days compared to 9 days (Table 2b). However, the capture of *P. madidus* was found by regression analysis to significantly increase ($P=0.005$) as the emptying frequency was decreased (Fig. 1). Staphylinidae and Araneae catches were unaffected by emptying frequency.

Table 1. Composition of the total catch over nine days.

Group	N
Pterostichus madidus	6691
Other Carabidae	203
Staphylinidae	111
Other Coleoptera	431
Linyphiidae	1487
Other Araneae	34

Table 2. The frequency of trap emptying on the mean number of individuals (±1 SE) per trap in a 6 and 9 day trial.

(a) Six-day trial emptied every 1, 2, 3 or 6 days

Emptying frequency	1	2	3	6	$F_{3,36}$	P
P. madidus	75±9	94±13	84±9	141±12	5.3	0.004
Carabidae	76±10	96±13	85±9	142±13	5.2	0.004
Coleoptera	82±11	103±15	95±11	149±13	4.7	0.008
Staphylinidae	1.3±0.5	1.7±0.6	0.8±0.2	1.6±0.4	0.6	>0.05
Araneae	26±2.8	24±3.0	22±2.4	21±3.4	0.6	>0.05

(b) Nine-day trial emptied every 1, 3 or 9 days

Emptying frequency	1	3	9	$F_{3,36}$	P
P. madidus	97±12	118±13	163±15	6.0	0.007
Carabidae	100±12	120±14	171±17	6.0	0.007
Coleoptera	110±14	134±15	181±17	5.6	0.009
Staphylinidae	1.7±0.6	1.0±0.4	3.7±1	2.7	>0.05
Araneae	33±4.3	29±3.1	31±3.1	0.2	>0.05

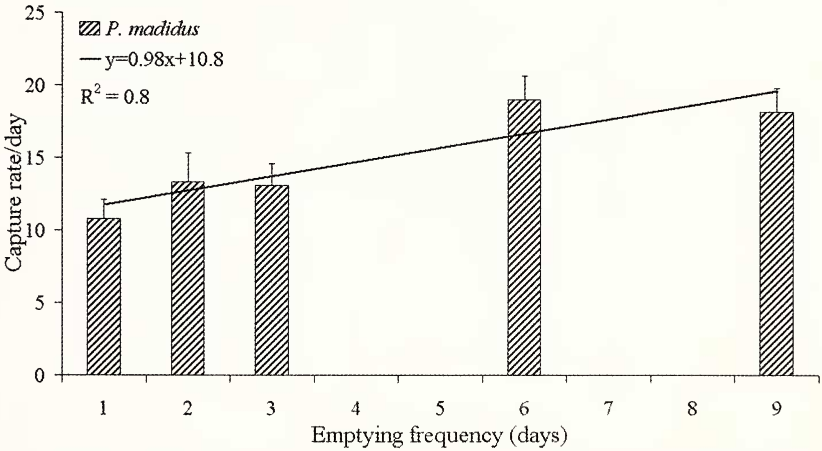

Figure 1. Effect of emptying frequency on the capture rate of *Pterostichus madidus*.

Discussion

The carabid *P. madidus* dominated the catch of epigeal invertebrates, because this is a large active species which is readily captured in pitfall traps and it was also very abundant in this field at the time of sampling. The capture of *P. madidus* also increased if the traps were emptied less frequently indicating that attraction was occurring. Moreover, this attraction effect was most noticeable after six days indicating that this species was relatively sensitive to the presence of other beetles in the traps. This may have occurred through a variety of mechanisms. The beetles may have been attracted to the odour generated from the dead beetles in the traps, which although masked to some extent by the preservative became more noticeable as the traps were emptied less frequently. Males may have been attracted to females captured in the traps but this would need verification. This has been found to occur with live pitfall trapping (Thomas & Sleeper, 1977). Dying beetles may emit an audio or chemical signal that attracts other beetles. Whatever the mechanism, demonstrating that attraction occurs has implications for how the data from pitfall trapping are interpreted. Further work is needed to verify whether attraction occurs for other species and between species, but it is likely that attraction will occur when other large carabid species (pers. obs.) are in abundance. Whether there is an interaction between the type of fluid used in the trap and emptying frequency also needs investigation, especially as it is already known that there is differential attraction between species using the same fluid (Adis, 1979). Whether the linear increase in attraction continues to increase beyond the nine-day period measured here also needs examining.

The study indicates that when emptying frequency differed between and within studies, converting total capture to a capture rate per day may generate some bias and should be avoided. Every effort should be made to standardise the emptying frequency within studies if numbers captured are to be measured. Even where season long capture is used, emptying frequency needs to be standardised within a study. Likewise, this should be done if a comparison is made with another study whilst also ensuring that all other factors known to influence capture efficiency, such as size of trap and preservative (Spence & Niemelä, 1994) are kept constant.

Despite the extensive research conducted on pitfall traps and their widespread use, there still remains considerable variation in their design and use. A standardised procedure and design as recommended by Adis (1979) has yet to be developed even though this would greatly enhance the opportunities for comparative ecological research.

Acknowledgements

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References

Adis J. 1979. Problems of interpreting arthropod sampling with pitfall traps. *Zoologischer Anzeiger Jena* **202**: 177–184.

Greenslade P. 1964. Pitfall trapping as a method for studying populations of Carabidae (Coleoptera). *Journal of Animal Ecology* **33**: 301–310.

Halsall N.B. & Wratten S.D. 1988. Video recording of aphid predation by Carabidae in a wheat crop. *Brighton Crop Protection Conference: Pests and Diseases*, 1988. Vol. 3, pp. 1047–1052.

Holland J.M., Begbie, M., Birkett, T., Southway, S., Thomas, S.R., Alexander, C.J. & Thomas, C.F.G. 2004. The spatial dynamics and movement of *Pterostichus melanarius* and *P. madidus* (Carabidae) between and within arable fields in the UK. *International Journal of Ecology and Environmental Sciences* **30**: 35–50.

Holopainen J.K. & Varis A.L. 1986. Effects of a mechanical barrier and formalin preservative on pitfall catches of carabid beetles (Coleoptera, Carabidae) in arable fields. *Journal of Applied Entomology* **102**: 440–445.

Luff M.L. 1975. Some features influencing the efficiency of pitfall traps. *Oecologia* **19**: 345–357.

Spence J.R. & Niemelä J.K. 1994. Sampling carabid assemblages with pitfall traps: the madness and the method. *The Canadian Entomologist* **126**: 881–894.

Sunderland K.D., De Snoo G.R., Dinter A., Hance T., Helenius J., Jepson P., Kromp B., Samu F., Sotherton N.W., Ulber B. & Vangsgaard C. 1995. Density estimation for beneficial predators in agroecosystems. *Acta Jutlandica* **70**: 133–164.

Thomas D.B. & Sleeper E.L. 1977. The use of pit-fall traps for estimating abundance of invertebrates, with special reference to the Tenebrionidae (Coleoptera). *Annals of the Entomological Society of America* **70**: 242–248.

Ulber B. & Wolf-Schwerin G. 1995. A comparison of pitfall trap catches and absolute density estimates of carabid beetles in oilseed rape fields. *Acta Jutlandica* **70**: 77–86.

Weeks R.D. & McIntyre N.E. 1997. A comparison of live versus kill pitfall trapping techniques using various killing agents. *Entomologia Experimentalis et Applicata* **82**: 267–273.

SHORT COMMUNICATION

***Heleodromia irwini* Wagner (Diptera: Empididae), an English boreo-alpine relict?** – *Heleodromia irwini* was first described (Wagner, 1985, A revision of the genus *Heleodromia* (Diptera, Empididae) in Europe. *Aquatic Insects* **7**: 33–43) from material collected on shingle and sand around the Dorback Burn [VC 95] and the European Alps. These and subsequent records from the Rivers Dee, River Lui and in Glen Derry (Falk & Crossley, 2005. A review of the scarce and threatened flies of Great Britain. Part 3: Empidoidea. *Species Status* **3**: 1–134. JNCC, Peterborough) suggest an exclusively boreo-alpine distribution with adults associated with exposed marginal sediments of upland rivers and streams. On 8.vii.2005 I found a male specimen at the edge of a narrow, shallow stream passing through an area of 'sugar' limestone but which originated from a small area of blanket bog immediately upstream on Widdybank Fell, Upper Teesdale (NZ 8130, VC 66). Upper Teesdale is well known for its relict boreo-alpine fauna and flora and it is suggested that this isolated occurrence of *H. irwini*, well removed from its Scottish and Alpine populations may be indicative of a post-glacial relict population marooned by retreating ice at the end of the last glaciation. – ADRIAN PLANT, Department of Biodiversity and Systematic Biology, National Museum of Wales, Cardiff, CF10 3NP.